

# REGIONAL DOWNSCALING OF THE 50-YEAR NCEP/NCAR REANALYSIS FOR CALIFORNIA AND THE UNITED STATES

Hideki Kanamaru, Masao Kanamitsu,  
John Roads and Dan Cayan  
(Scripps Institution of Oceanography)  
John Helly and Yifeng Cui  
(San Diego Supercomputer Center)

## Purpose

- ◆ Provide long-term high-resolution analysis of atmosphere and land for use in regional climate studies.
- ◆ Dynamically, thermo-dynamically and hydrologically consistent analysis.
  - This cannot be achieved by statistical method.

## Research goal of regional global change study

- ◆ Understand complex mutual interactions among various atmospheric, oceanic and land states for global change.
  - ◆ Precipitation ← humid air + cloud cover
  - ◆ Precipitation ← storms → low pressure + strong winds
  - ◆ Cloud cover → lower temperature
  - ◆ Precipitation → wetter soil → river flow
  - ◆ Precipitation in solid form → snow pack → water storage → lower spring temperature
  - ◆ Lower surface temperature → change in low level circulation
  - These interactions are further complicated by orography, remote SST forcing, urbanization, land use and may other external factors.
- ◆ For this purpose, physically consistent long term analysis of atmosphere and land is essential.

## Project Overview

- ◆ 50-year downscaling of the NCEP/NCAR reanalysis.
- ◆ Regional Spectral Model (RSM) at ECPC/SIO.
- ◆ 10 km, 28 level with hourly output.

## Project Overview - detail

- ◆ Two computing projects
  - Earth Simulator Center in Japan
    - ◆ Very large domain covering entire US and a part of Pacific, Atlantic and Gulf of Mexico
  - San Diego Super Computing Center and NPACI
    - ◆ Smaller domain covering entire state of California and surrounding areas.
    - ◆ Sensitivity studies, such as urbanization and land use.
- ◆ Only difference in domain.
- ◆ In order to make the computations tractable, multiple-stream run will be performed.
  - May suffer from soil moisture spin-up.

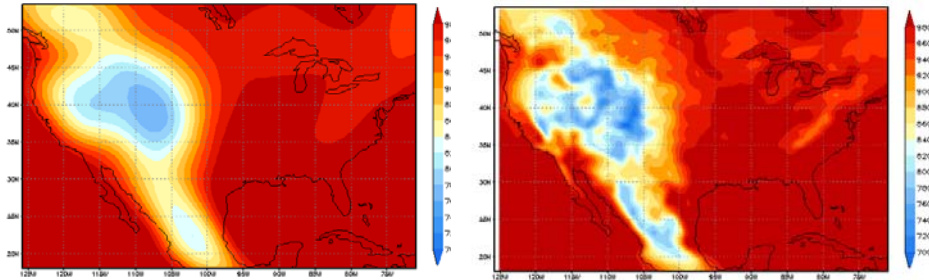
## Regional Spectral Model (RSM)

- ◆ The RSM is nested within the Global Spectral Model (GSM).
- ◆ Physics and dynamics – consistent with the NCEP/NCAR reanalysis model.
- ◆ Hydrostatic model (10km max resolution)
- ◆ Spectral formulation of difference between global and regional fields.
- ◆ Sine and cosine functions.

# Downscaled Surface pressure field

Reanalysis resolution

30km resolution



## Technical problem

- one of the most serious regional model problems -

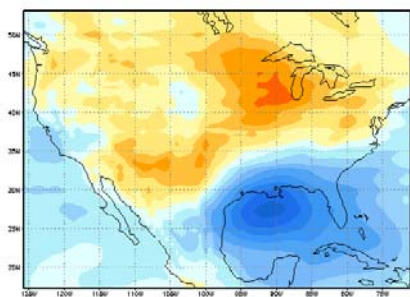
- ◆ Mathematically, regional model is an ill-posed problem. Boundary nudging is the technical solution but not total solution.
- ◆ The simulations depends on the domain size and boundary nudging technique.
- ◆ The essence of the problem is that the regional solution departs from global scale analysis (boundary forcing) field.
- ◆ Forcing the regional model solution to global analysis fields inside the regional domain, but retains small scales.

## Spectral tendency damping

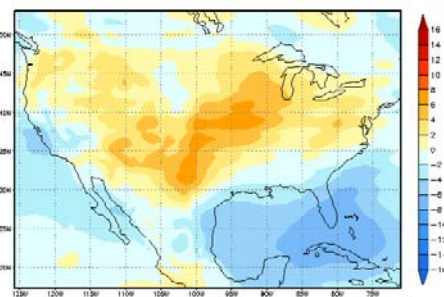
- ◆ Similar, in function, to spectral nudging of von Storch et al. (2000).
- ◆ Nudges the regional atmospheric states to the large-scale analysis.
- ◆ Physical scale 1000km or larger.
- ◆ Suppress the tendency of winds.
- ◆ Damp the area-mean perturbation of  $T$ ,  $q$ , and  $P_s$ .

## 500mb height, June 2000 deviations from reanalysis

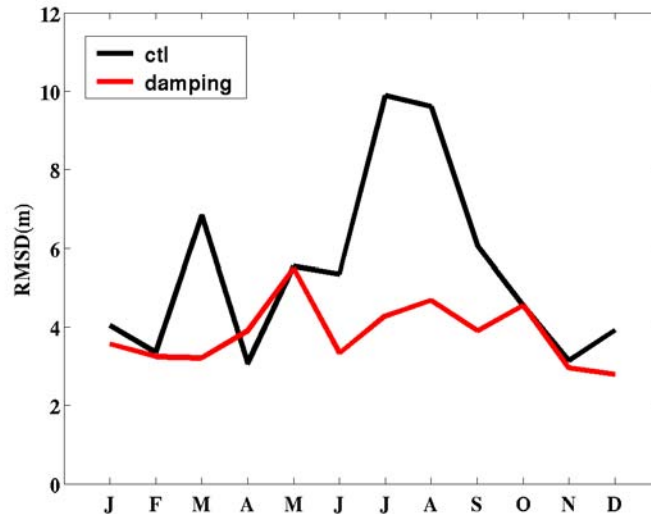
**Control run  
- reanalysis**



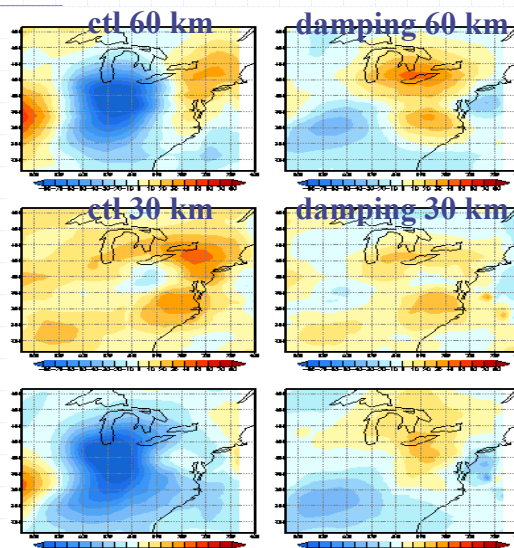
**Damping run  
- reanalysis**



## 500mb height RMSD from reanalysis

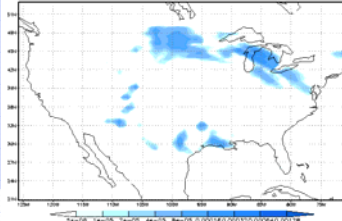


## 500mb height Sensitivity to resolution

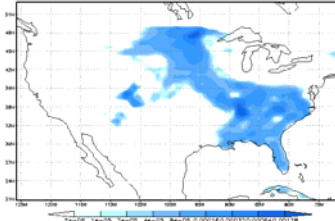


# Precipitation July 12<sup>th</sup>, 2000

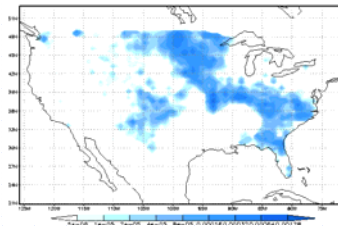
Control run



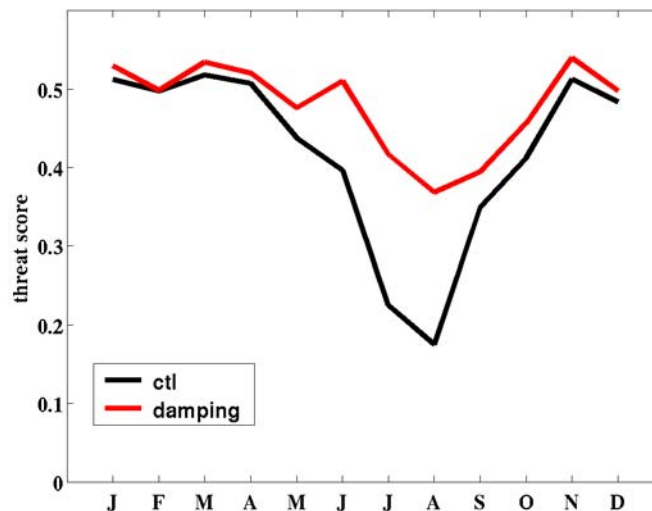
Damping run



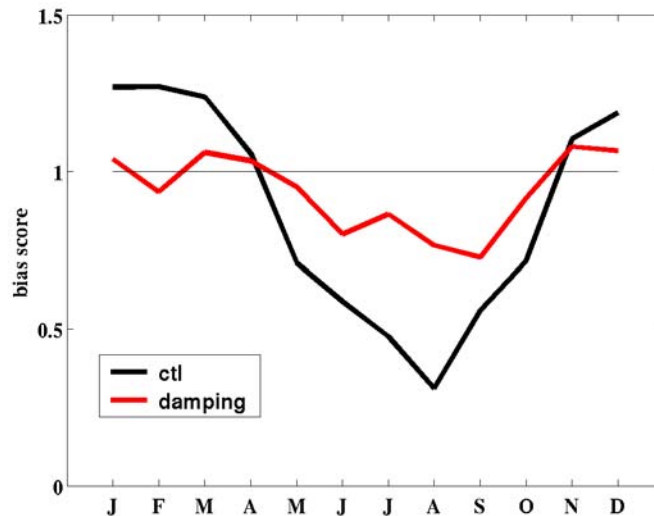
Observation



# Precipitation Threat score above .01 in./day



## Precipitation Bias score above .01 in./day

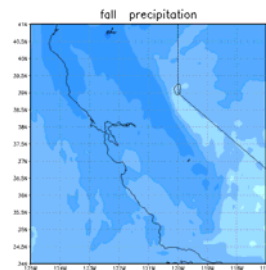
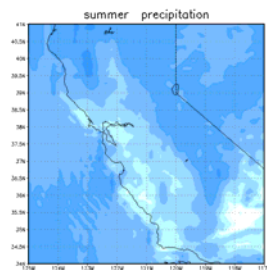
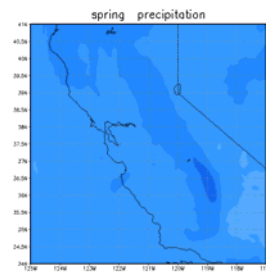
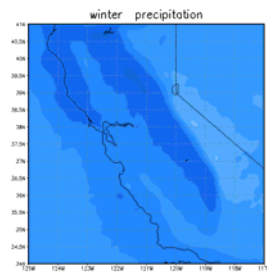


## Current status

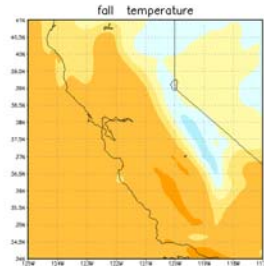
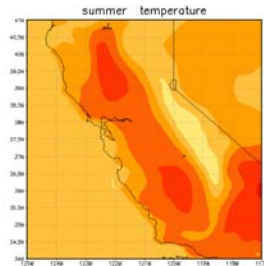
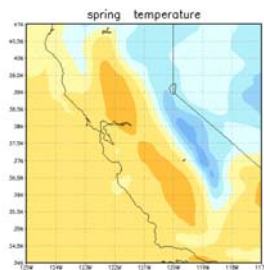
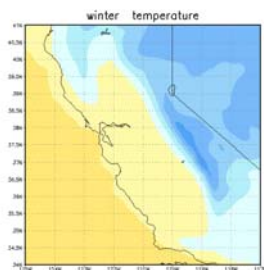
- ◆ Finalized the downscaling method (spectral tendency damping).
- ◆ Trial run on the Earth Simulator in Dec. 2003 and May 2004.
  - More aggressive optimization necessary and is in progress
- ◆ Started State of California runs on SDSC datastar. 3-4 years complete.



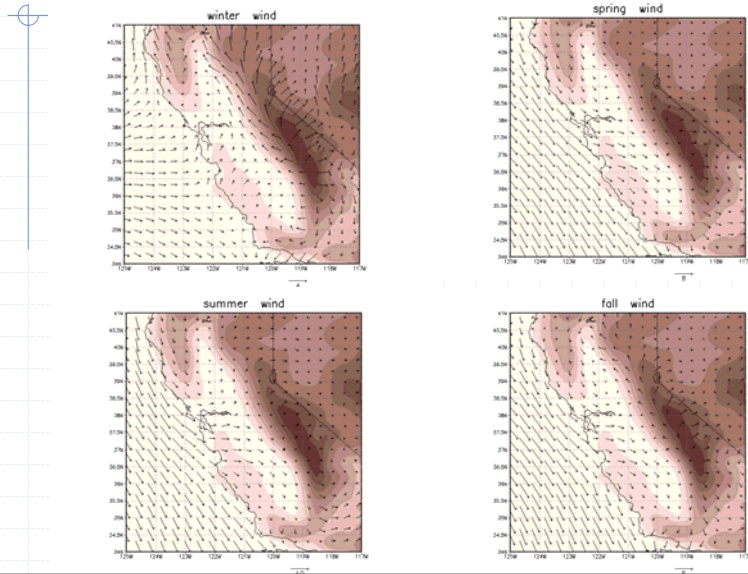
# Precipitation climatology



# Sfc temperature climatology



# Wind climatology



## Products

- ◆ 10km resolution, hourly output
- ◆ GRIB format.
- ◆ File size
  - California domain
    - ◆ ~185 Mb per day
  - US domain
    - ◆ ~3 GB per day

## Available outputs (1)

- Pressure levels (hPa)

1000	925	850	700	600	500	400	300	250	200
150	100	70	50	30	20	10			

Geopotential height

Zonal wind component

Meridional wind component

Temperature

Relative humidity

Specific humidity

Vertical p-velocity

Vorticity

## Available outputs (2)

- |   |  |
|---|--|
| 1. Surface Pressure                                 | 20. Sensible heat flux   |
| 2. Surface Pressure tendency                        | 21. Latent heat flux   |
| 3. Precipitable water                               | 22. Surface skin temperature                                     |
| 4. Relative humidity of atmospheric column          | 23. Water equiv. of accum. snow depth                            |
| 5. Tropopause temperature                           | 24. Downward long wave radiation flux at the surface             |
| 6. Tropopause pressure                              | 25. Upward long wave radiation flux at the surface               |
| 7. Tropopause zonal wind                            | 26. Upward long wave radiation flux at the top of the atmosphere |
| 8. Tropopause meridional wind                       | 27. Upward solar radiation flux at the top of the atmosphere     |
| 9. Vertical wind speed shear at tropopause          | 28. Upward solar radiation flux at the surface                   |
| 10. Surface lifted index                            | 29. Downward solar radiation flux at the surface                 |
| 11. Best (4-layer) lifted index                     | 30. Downward solar radiation flux at the top of the atmosphere   |
| 12. Maximum wind level temperature                  | 31. High cloud cover   |
| 13. Maximum wind level pressure                     | 32. High cloud top pressure                                      |
| 14. Maximum wind level zonal wind                   | 33. High cloud bottom pressure                                   |
| 15. Maximum wind level meridional wind              |  |
| 16. Surface geopotential height (surface elevation) |  |
| 17. Mean sea level pressure                         |  |
| 18. Zonal component of momentum flux                |  |
| 19. Meridional component of momentum flux           |  |

## Available outputs (3)

- |                                   |  |
|-----------------------------------|--|
| 34. High cloud top temperature    | 55. Runoff   |
| 35. Middle cloud cover            | 56. Potential evaporation rate                       |
| 36. Middle cloud top pressure     | 57. Cloud work function                              |
| 37. Middle cloud base pressure    | 58. Zonal gravity wave stress                        |
| 38. Middle cloud top temperature  | 59. Meridional gravity wave stress                   |
| 39. Low cloud cover               | 60. PBL height                                       |
| 40. Low cloud top pressure        | 61. Albedo   |
| 41. Low cloud base pressure       | 62. Total cloud cover                                |
| 42. Low cloud top temperature     | 63. Convective cloud cover                           |
| 43. Precipitation rate            | 64. Snowfall rate water equivalent                   |
| 44. Convective precipitation rate | 65. Snow sublimation heat flux                       |
| 45. Ground heat flux              | 66. Snow melt heat flux                              |
| 46. Land-sea mask                 | 67. E-W component of column integrated moisture flux |
| 47. Sea Ice concentration         | 68. N-S component of column integrated moisture flux |
| 48. 10 meter zonal wind           | 69. Soil moisture (2-layers)                         |
| 49. 10 meter meridional wind      | 70. Soil temperature (2-layers)                      |
| 50. 2m temperature                |  |
| 51. 2m specific humidity          |  |
| 52. Surface roughness             |  |
| 53. Maximum temperature           |  |
| 54. Minimum temperature           |  |

## Data Availability

- SIO/ECPC data server
- SDSC data server
  - Will consider easier access by separating variables, or generating time series.

## Future plans

- Complete 50 years over California domain
- Perform sensitivity study (irrigation and land use).
- Perform 50 years over US using Earth Simulator
  
- Precipitation assimilation
- Land surface model impact study
- Snow pack model